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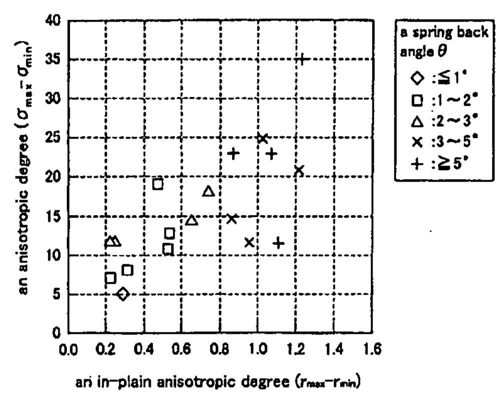
(54) **FERRITIC STAINLESS STEEL STRIP EXCELLENT IN FREEZE OF SHAPE FORMED BY WORKING**

(57) A ferritic stainless steel sheet, which is press-formed to a product shape without such dimensional defects as spring-back or torsion, has an alloying composition consisting of C up to 0.10%, Si up to 1.0%, Mn up to 1.0%, P up to 0.050%, S up to 0.020%, Ni up to 2.0%, 8.0-22.0% of Cr, N up to 0.05%, optionally one or more of Al up to 0.10%, Mo up to 1.0%, Cu up to 1.0%, 0.010-0.50% of Ti, 0.010-0.50% of Nb, 0.010-0.30% of V, 0.010-0.30% of Zr and 0.0010-0.0100% of B, and the balance being essentially Fe with the provision that a value-FM defined by the formula (1) is adjusted to 0 or less. Its mechanical properties are controlled to a plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) ≤0.80 and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength ≤20N/mm^2. The stainless steel sheet is manufactured by hot-rolling a stainless steel having the specified composition and then batch-annealing the hot-rolled steel sheet 1-24 hours at 700-800 °C.

$$FM=420C-11.5Si+7Mn+23Ni-3.5Cr-12Mo+9Cu$$
$$-49Ti-50Nb-23V-52Al+470N+20 \quad (1)$$

FIG.2



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Description

INDUSTRIAL FIELD OF THE INVENTION

[0001] The present invention relates to a ferritic stainless steel sheet, which can be formed to a product shape by press-forming, bending, roll-forming or the like due to good shape-freezability with less dimensional defects such as spring-back and torsion after forming, and also relates to a method of manufacturing thereof.

BACKGROUND

[0002] A stainless steel sheet has been used in various fields, e.g. interior or exterior members of buildings, frame members of electric home appliances and kitchen goods, due to its excellent external appearance and corrosion-resistance. The wording of "a steel sheet" involves a steel strip in this specification.

[0003] A product formed from a stainless steel sheet often involves dimensional defects originated in elastic recovery, since elastic strain of the stainless steel sheet is bigger than a common steel sheet. For instance, when a steel sheet, which is simply bent to a product shape, is detached from a shaping die, an angle of bent becomes broader than a designed angle due to release of elastic strain. The reformation is so-called as "spring-back". Especially in the case where a product is manufactured from a steel sheet by shallow drawing, elastic stain is not completely released but remains at a flange or a punched bottom even after the product is detached from a shaping die. The residual strain causes defects such as torsion and significantly reduces commercial value of the product.

[0004] A relatively soft austenitic stainless steel sheet such as SUS304 has been used among various kinds of stainless steels, in order to inhibit occurrence of defects during fabrication. However, austenitic stainless steel is expensive material due to high Ni content.

SUMMARY OF THE INVENTION

[0005] The present invention aims at provision of a ferritic stainless steel sheet, which is cheaper material due to remarkable decrease of Ni content but is improved in shape-freezability so as to inhibit dimensional defects such as spring-back and torsion after forming.

[0006] The present invention proposes a new ferritic stainless steel sheet, which has the alloying composition consisting of C up to 0.10 mass %, Si up to 1.0 mass %, Mn up to 1.0 mass %, P up to 0.050 mass %, S up to 0.020 mass %, Ni up to 2.0 mass %, 8.0-22.0 mass % of Cr, N up to 0.05 mass %, optionally one or more of 0.01-0.50 mass % of Ti, 0.01-0.50 mass % of Nb, 0.01-0.30 mass % of V, 0.01-0.30 mass % of Zr and 0.0010-0.0100 mass % of B, and the balance being essentially Fe, with the provision that a value FM defined by the formula (1) is adjusted to 0 or less. The ferritic stainless steel sheet has an in-plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) ≤0.80 and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength ≤20 N/mm^2.

$$FM=420C-11.5Si+7Mn+23Ni-3.5Cr-12Mo+9Cu$$
$$-49Ti-50Nb-23V-52Al+470N+20 \quad (1)$$

[0007] The stainless steel sheet preferably has 0.2%-yield strength ≤350 N/mm^2 along any of a rolling direction (Direction-L), directions (Direction-D) crossing Direction-L with an angle of 45 degrees and a traverse direction (Direction-T) crossing Direction-L with a right angle.

[0008] The stainless steel sheet is manufactured by hot-rolling a ferritic stainless steel having the specified composition and then batch-annealing the hot-rolled steel sheet 1-24 hours at 700-880 °C.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

Fig. 1 is a schematic view for explaining a bending test, whereby a steel sheet is bent to a box shape, and corners of the box are measured for evaluation of spring-back.

Fig. 2 is a graph for explaining a spring-back angle in relation with a plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength.

PREFERRED EMBODIMENTS OF THE INVENTION

[0010] Properties of ferritic stainless steels substantially depend on chemical composition and manufacturing conditions. The inventors have researched and examined effects of the chemical composition and manufacturing conditions on the properties, and discovered that shape-freezability (in other words, suppression of deformation derived from spring-back after forming) is improved by combination of a specified alloying composition with manufacturing conditions.

[0011] Since the shape-freezability is influenced not only by uniaxial deformation but also multi-axial deformation during plastically forming a stainless steel sheet to a product shape, materialistic properties and anisotropy along various directions put big effects on the shape-freezability. Especially, deviations of Lankford values (r) and 0.2%-yield strength among Directions-L, -D and -T are main factors. As the deviations of Lankford values (r) along directions-L, -D and -T are smaller, the stainless steel sheet has less plane anisotropy.

[0012] If Lankford value (r) is different from each other along Directions-L, - D and -T, thickness reduction of a stainless steel sheet is deviated at every part to which the same stress is applied. Deviation of thickness reduction causes irregular distribution of residual strains in the stainless steel sheet formed to a product shape, resulting in poor shape-freezability. Deviation of 0.2%-yield strength from each other along Directions-L, -D and -T means that various strains different from each other are given to the stainless steel sheet during plastically forming the stainless steel sheet with a certain stress. In this case, the shape-freezability is also poor.

[0013] In order to improve shape-freezability, a plane anisotropic degree (r_{max}-r_{min}) and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength are necessarily decreased, wherein r_{max} and σ_{max} are maximum of Lankford value (r) and 0.2%-yield strength among Directions-L, -D and -T, while r_{min} and σ_{min} are minimum of Lankford value (r) and 0.2%-yield strength among Directions-L, -D and -T.

[0014] The plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) and the anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength are decreased by conditioning re-crystallized ferrite grains of the stainless steel sheet to an isotropic state with equation of planar orientation. Isotropic re-crystallization of ferrite grains is attained by precipitating dissolved C and N as fine carbonitride particles uniformly dispersed in a steel matrix. Isotropic re-crystallization of ferrite grains effectively reduces the anisotropic degrees (r_{max}-r_{min}, σ_{max}-σ_{min}). Effects of uniform dispersion of fine carbonitride particles on random growth of re-crystallized ferrite grains are explained as follows:

[0015] Carbonitride particles present in a steel matrix act as seeds for re-crystallization of ferrite grains during final annealing, e.g. batch-annealing or finish-annealing, of a stainless steel sheet. Although grain boundaries and deformed zones such as slip bands in a cold-rolled ferritic structure have been heretofore regarded as seeds for re-crystallization of ferrite grains, the grain boundaries and the deformed zones are elongated by cold-rolling. As a result, the grain boundaries and the deformed zones have specified orientation, and re-crystallized ferrite grains grow while succeeding to the orientation. On the other hand, carbonitride particles are granular and very hard (Vickers hardness above 1000), so that they are not elongated during cold-rolling but act as seeds for isotropic re-crystallization of ferrite grains at boundaries in contact with ferrite grains.

[0016] Uniform dispersion of fine carbonitride particles is assured by properly controlling annealing conditions, so as to reform a rolling texture generated in a former hot-rolling step to an isotropic ferrite structure. The isotropic structure is maintained even in a cold-rolled state. That is, each ferrite grain is orientated due to application of stress in a following cold-rolling step, but a whole of the ferrite grains is still homogeneous and isotropic. The uniformly dispersed fine carbonitride particles act as seeds for re-crystallization of ferrite grains from a cold-rolling step to an annealing step, so as to further uniform planar orientation of ferrite grains. Consequently, an in-plane anisotropic degree (r_{max}-r_{min}) is reduced, and a stainless steel sheet is press-formed with good shape-freezability.

[0017] The other features of the present invention will be apparent from the following explanation on an alloying composition and manufacturing conditions.

[0018] A ferritic stainless steel according to the present invention contains the following elements as essential components.

C up to 0.10 mass %

[0019] C is converted to carbides by batch-annealing, and the carbides act as seeds for random growth of ferrite grains during re-crystallization at a final-annealing step. However, C is an element which unfavorably raises strength of a cold-rolled stainless steel sheet after annealing. Excess C content is also disadvantage for toughness. Therefore, C content is controlled to 0.10 mass % or less.

Si up to 1.0 mass %

[0020] Si is an element, which is added as a deoxidizing agent during steel-making, but solution-hardens a steel

matrix too much. Since excess Si causes hardening and decrease of ductility, an upper limit of Si content is determined to 1.0 mass %.

Mn up to 1.0 mass %

[0021] Mn is an austenite former, which does not put harmful effects on steel material due to its small solution-hardening power, useful for controlling the value-FM defined by the formula (1). However, excess Mn causes generation of fumes during steel-making and worsens productivity. In this sense, Mn content is controlled to 1.0 mass % or less.

P up to 0.050 mass %

[0022] P is an element harmful on hot-workability. The effect of P is suppressed by controlling P content less than 0.050 mass %.

S up to 0.020 mass %

[0023] S is an element, which segregates at grain boundaries and worsens hot-workability Such effects are suppressed by controlling S content less than 0.020 mass %.

Ni up to 2.0 mass %

[0024] Ni is the same austenite former as Mn and useful for controlling the value-FM. However, excess addition of Ni above 2.0 mass % raises a steel cost and also hardens a steel sheet.

8.0-22.0 mass % of Cr

[0025] Cr is an essential element for corrosion resistance. At least 8 mass % of Cr is necessary for corrosion resistance as stainless steel. However, excess addition of Cr above 22.0 mass % worsens toughness and formability of a stainless steel sheet.

N up to 0.05 mass %

[0026] N is converted to nitrides by batch-annealing. The nitrides act as seeds for random growth of ferrite grains during re-crystallization in a final-annealing step. However, excess N causes decrease of toughness, since N raises strength of an annealed cold-rolled steel sheet. Therefore, N content is controlled to 0.05 mass % or less.

[0027] The ferritic stainless steel may further contain one or more of the following elements in addition to the above-mentioned elements.

Al up to 0.10 mass %

[0028] Al is an element, which is added as a deoxidizing agent during steel-making. Excess Al content above 0.10 mass % causes increase of non-metallic inclusions, decrease of toughness and occurrence of surface defects. Therefore, Al content is properly determined so as to control a value-FM to 0 or less.

Mo up to 1.0 mass %

[0029] Mo is an element for improvement of corrosion resistance, but excess addition of Mo above 1.0 mass % promotes solution-hardening and retards dynamic re-crystallization in a high-temperature zone, resulting in decrease of hot-workability.

Cu up to 1.0 mass %

[0030] Cu is an element included in steel from scraps during steel-making. Since excess Cu is unfavorable for hot-workability and corrosion-resistance, its upper limit is determined to 1.0 mass %.

0.01-0.50 mass % of Ti, 0.01-0.50 mass % of Nb,
0.01-0.30 mass % of V and 0.01-0.30 mass % of Zr

[0031] Ti, Nb and V are reacted with C dissolved in a steel matrix and precipitated as carbides effective for formability. Zr captures dissolved O as oxide and improves formability and toughness of a stainless steel sheet. Effects of these elements are noted at every 0.01 mass % or more, but excess addition is disadvantageous for productivity. In this sense, upper limits of these elements are determined to Ti: 0.50 mass %, Nb: 0.50 mass %, V: 0.30 mass % and Zr: 0.30 mass %.

0.0010-0.0100 mass % of B

[0032] B is an element, which uniformly disperses transformed phase in a hot-rolled steel sheet and promotes random growth of ferrite grains in a final structure without generation of aggregate structure. Uniform distribution of the transformed phase is typically noted by addition of B at a ratio of 0.0010 mass % or more. However, excess addition of B above 0.0100 mass % causes degradation of hot-workability and weldability.

A value-FM not more than 0

[0033] The stainless steel is designed so as to adjust a value-FM defined by the formula (1) to 0 or less in addition to the specified ratios of the alloying elements, for improvement of shape-freezability without generation of an austenite phase during batch-annealing.

$$FM=420C-11.5Si+7Mn+23Ni-3.5Cr-12Mo+9Cu$$

$$-49Ti-50Nb-23V-52Al+470N+20 \qquad (1)$$

[0034] Generation of an austenite phase in a high-temperature zone during batch-annealing is inhibited by controlling the value-FM to 0 or less. On the other hand, an alloying design at FM>0 allows generation of an austenite phase, which can dissolve C and N at relatively high ratios, in a ferrite matrix. Since solubility of C and N is different between the austenite phase and the ferrite matrix, the anisotropic degrees (r_{max}-r_{min} and σ_{max}-σ_{min}) are raised due to the uneven solubility.

An in-plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) ≤0.80

An anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength ≤20N/mm^2

[0035] As the anisotropic degrees (r_{max}-r_{min} and σ_{max}-σ_{min}) are smaller, a ferritic stainless steel is press-formed to a product shape with better shape-freezability. Experimental results prove that the shape-freezability is excellent at (r_{max}-r_{min}) ≤0.80 and (σ_{max}-σ_{min}) ≤ 20N/mm^2.

0.2%-yield strength ≤ 350N/mm^2

[0036] A complete ferrite structure free from martensite with 0.2%-yield strength of 350N/mm^2 or less is preferable in order to impart excellent shape-freezability to a ferritic stainless steel. Strength above 350N/mm^2 naturally requires application of a big stress for plastic deformation of the stainless steel sheet, resulting in increase of spring-back and degradation of shape-freezability.

Annealing 1-24 hours at 700-880 °C

[0037] A ferritic stainless steel sheet is annealed under the conditions that dissolved C and N are precipitated as fine carbonitride particles uniformly dispersed in a single ferrite matrix, in order to reduce the anisotropic degrees (r_{max}-r_{min} and σ_{max}-σ_{min}). Sufficient precipitation of carbonitride particles is realized by batch-annealing at a temperature of 700 °C or higher. However, when the stainless steel sheet is batch-annealed at a temperature higher than 880 °C, the stainless steel sheet is rendered to an anisotropic structure on the contrary due to predominant growth of re-crystallized ferrite grains (so-called as "secondary re-crystallization").

[0038] The present invention will be more clearly understood by the following examples.

[0039] Several stainless steels shown in Table 1 were melted in a vacuum furnace, cast, forged and then hot-rolled to thickness of 3.0 mm. Each hot-rolled steel sheet was batch-annealed or intermediate-annealed under conditions shown in Table 2, pickled and then cold-rolled to thickness of 0.5 mm. The cold-rolled steel sheet was finish-annealed 1 minute at 880 °C, cooled in the open air and then pickled again.

TABLE 1: Chemical Compositions and Value-FM of Stainless Steels

Steel Kind	Alloying components (mass %)									Value-FM	Note
	C	Si	Mn	P	S	Ni	Cr	N	Others		
A	0.034	0.75	0.80	0.035	0.008	0.02	14.65	0.021		- 9.7	Inventive Examples
B	0.036	0.81	0.30	0.029	0.002	1.48	21.85	0.010		- 9.8	
C	0.008	0.10	0.21	0.033	0.005	0.17	11.34	0.021	Cu:0.23,Ti:0.18	- 9.0	
D	0.022	0.34	0.51	0.035	0.006	0.01	16.08	0.007	Cu:0.45,Ti:0.21,Al:0.09,B:0.0035	- 34.8	
E	0.023	0.78	0.45	0.033	0.002	0.95	12.56	0.045	Mo:0.74,Ti:0.43,Zr:0.21	- 7.1	
F	0.015	0.03	0.34	0.033	0.005	0.35	11.40	0.011	Nb:0.42	- 19.3	
G	0.075	0.50	0.26	0.042	0.007	0.11	21.23	0.010	Cu:0.65,V:0.23	- 18.9	
H	0.006	0.43	0.64	0.026	0.005	0.89	13.23	0.034	B:0.0023	12.2	Comparative Examples
I	0.076	0.87	0.26	0.042	0.009	1.64	21.40	0.032	Nb:0.32	5.6	
J	0.056	0.78	0.87	0.048	0.006	0.26	12.43	0.045	Mo:0.56,Ti:0.18,Zr:0.24	8.7	
K	0.075	0.24	0.30	0.033	0.012	2.23	16.23	0.010	Cu:0.30,Al:0.07	49.1	

The underlined figures are out of ranges defined by the present invention.

[0040] Each annealed steel sheet was sampled for measurement of Lankford value (r) and 0.2%-yield strength as

follows:

Lankford value (r)

[0041] After tensile strain of 15% was applied to a test piece JIS 13B, Lankford value (r) was measured along each of Directions-L, -D and -T. A difference between measured maximum and minimum values was calculated and evaluated as an in-plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r).

0.2%-yield strength

[0042] After tensile strain was applied to a test piece JIS 13B at a rate of 3.3×10^{-4}, 0.2%-yield strength was measured along each of Directions-L, -D and -T. A difference between measured maximum and minimum values was calculated and evaluated as an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength.

Shape-freezability

[0043] Two test pieces, each of which had a developed box-shape (shown in Fig. 1) comprising a 40 mm-square area E_1, E_2 with four oblong areas A_1-D_1, A_2-D_2 of 10 mm×36 mm in size, were prepared from each annealed steel sheet. One test piece was cut along Direction-L (a rolling direction), and the other was cut along Direction-D. All sides of the square areas E_1, E_2 were bent at a working speed of 200 mm/minute under a hold-down pressure of 20 ton, and the oblong areas A_1-D_1, A_2-D_2 were raised upright, by a 200-ton press equipped with a rectangular punch having a tip diameter of 4mm. A spring-back angle θ was measured at every measurement point P_1-P_4 corresponding to four corners of a bottom of a formed box. Shape-freezability was evaluated by a maximum angle θ_{max} among the measurement values.

[0044] Table 2 shows results of each annealed steel sheet, and Fig. 2 shows distribution of maximum spring-back angles θ_{max} in relation with anisotropic degrees (r_{max}-r_{min} and σ_{max}-σ_{min}).

[0045] It is understood from Fig. 2 that the inventive steel sheets with r_{max}-r_{min} ≤0.8 and σ_{max}-σ_{min} ≤20N/mm^2 were good of shape freezability (i.e. maximum spring-back angles θ_{max} ≤3 degrees). On the other hand, comparative steel sheets, which did not satisfy either one of r_{max}-r_{min} ≤0.8 and σ_{max}-σ_{min} ≤20N/mm^2, were poor of shape-freezability, as noted by maximum spring-back angles θ_{max} >3 degrees

TABLE 2: Manufacturing Conditions and Properties of Stainless Steel Sheets

Test No.	Steel Kind	Batch-annealing or Intermediate annealing		In-plane anisotropy	0.2%-yield strength	Anisotropic degree of 0.2%-yield strength	Maximun sping back angle	Note
		°C	Period	$r_{max}-r_{min}$	$\sigma_{max}(N/mm^2)$	$\sigma_{max}-\sigma_{min}(N/mm^2)$	θ_{min}(degrees)	
1	A	720	12 hrs.	0.53	256	11	1.7	Inventive Examples
2	A	770	8 hrs	0.65	276	15	2.2	
3	A	835	20 hrs.	0.24	234	12	2.6	
4	A	750	60 sec.	1.07	276	23	5.2	Comparative Examples
5	A	930	10 hrs.	0.86	241	15	4.6	
6	C	775	10 hrs.	0.32	203	8	1.8	Inventive Examples
7	C	845	20 hrs.	0.29	199	5	0.9	
8	C	670	20 hrs.	0.96	219	12	3.9	Comparative Examples
9	C	1000	60 sec.	1.02	232	25	4.3	
10	B	890	8 hrs.	0.23	322	7	1.6	Inventive Examples
11	D	790	10 hrs.	0.74	289	18	2.3	
12	E	835	18 hrs.	0.22	215	12	2.8	
13	F	850	8 hrs.	0.48	221	19	1.7	
14	G	765	22 hrs.	0.54	331	13	1.6	
15	H	750	8 hrs.	1.21	222	21	4.7	Comparative Examples
16	I	750	12 hrs.	1.11	312	12	6.5	
17	J	830	20 hrs.	0.87	254	23	7.3	
18	K	850	15 hrs.	1.23	392	35	8.5	

The underlines figures are out of the ranges defined by the present invention.

INDUSTRIAL APPLICABILITY

[0046] According to the present invention as above-mentioned, a ferritic stainless steel sheet is improved in shape-freezability by conditioning re-crystallized ferrite grains to a structure with equalized planar orientation so as to reduce a plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength to possible lowest values. Since the stainless steel sheet is plastically formed to a product shape with less spring-back, it is useful in various industrial fields, e.g. parts of electric or electronic devices such as a sealing member of an organic EL device, precise pressed parts, and building members.

Claims

1. A ferritic stainless steel sheet, which has:

   alloying composition consisting of C up to 0.10 mass %, Si up to 1.0 mass %, Mn up to 1.0 mass %, P up to 0.050 mass %, S up to 0.020 mass %, Ni up to 2.0 mass %, 8.0-22.0 mass % of Cr, N up to 0.05 mass % and the balance being essentially Fe, with the provision that a value-FM defined by the formula (1) is adjusted to 0 or less, and
   the mechanical properties that a plane anisotropic degree (r_{max}-r_{min}) of Lankford value (r) and an anisotropic degree (σ_{max}-σ_{min}) of 0.2%-yield strength are controlled not more than 0.80 and 20N/mm^2, respectively.

$$\mathrm{FM}=420\mathrm{C}-11.5\mathrm{Si}+7\mathrm{Mn}+23\mathrm{Ni}-3.5\mathrm{Cr}-12\mathrm{Mo}+9\mathrm{Cu}$$

$$-49\mathrm{Ti}-50\mathrm{Nb}-23\mathrm{V}-52\mathrm{Al}+470\mathrm{N}+20 \quad (1)$$

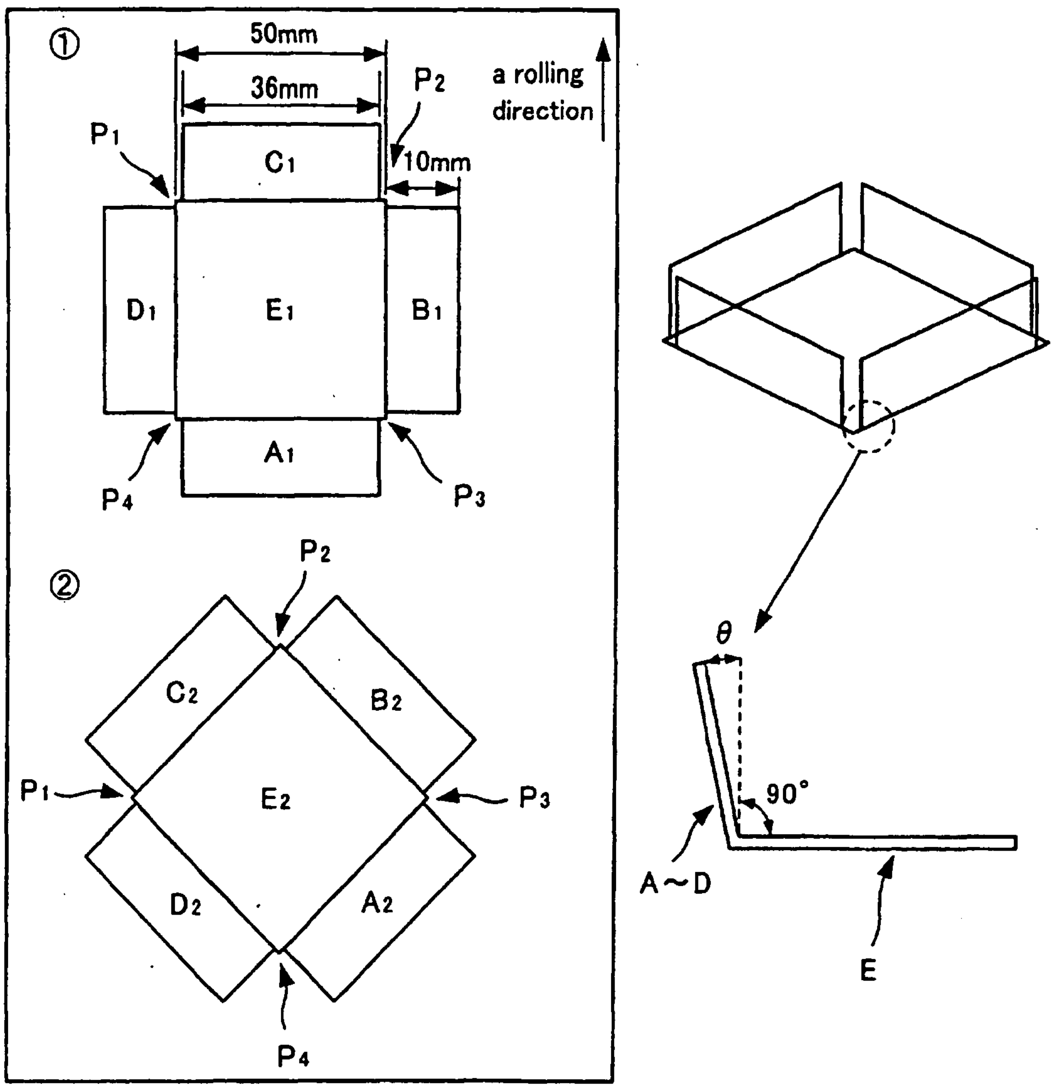
2. The ferritic stainless steel sheet defined by Claim1, wherein the alloying composition further contains one or more of Al up to 0.10 mass %, Mo up to 1.0 mass %, Cu up to 1.0 mass %, 0.01-0.50 mass % of Ti, 0.01-0.50 mass % of Nb, 0.01-0.30 mass % of V, 0.01-0.30 mass % of Zr and 0.0010-0.0100 mass % of B.

3. The ferritic stainless steel sheet defined by Claim 1, wherein 0.2%-yield strength is not more than 350N/mm^2 along any of a rolling direction, directions crossing said rolling direction with an angle of 45 degrees and a direction crossing said rolling direction with a right angle.

4. A method of manufacturing a ferritic stainless steel sheet good of shape-freezability during plastic reformation, which comprises the steps of:

   hot-rolling a ferritic stainless steel having the alloying composition defined by Claim 1 or 2, and then batch-annealing the hot-rolled steel sheet 1-24 hours at 700-800 °C.

FIG.1


①
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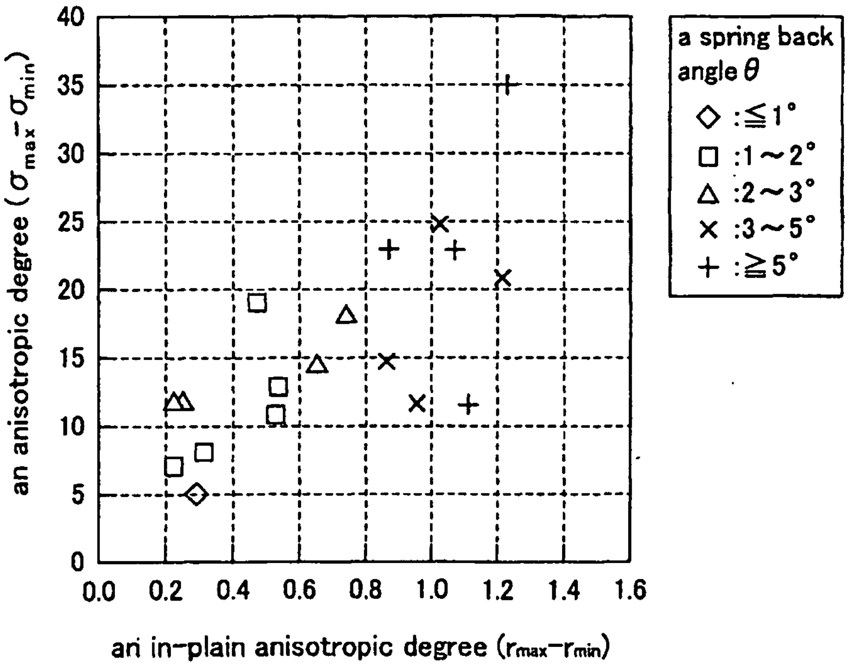
36mm
P2
a rolling direction
P1
C1
10mm
D1
E1
B1
A1
P4
P3
②
P2
C2
B2
P1
E2
P3
D2
A2
P4
θ
90°
A～D
E

FIG.2


a spring back angle θ
◇ :≦1°
□ :1～2°
△ :2～3°
× :3～5°
+ :≧5°
an anisotropic degree (σmax−σmin)
an in-plain anisotropic degree (rmax−rmin)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
5
10
15
20
25
30
35
40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/04524

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl7 C22C38/00, 38/40, 38/54, C21D9/46

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl7 C22C38/00-60, C21D9/46-48

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-2002
Kokai Jitsuyo Shinan Koho	1971-2002	Jitsuyo Shinan Toroku Koho	1996-2002

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2001-32050 A (Nippon Steel Corp.), 06 February, 2001 (06.02.01), Examples (Family: none)	1-4
X	JP 2001-32023 A (Nippon Steel Corp.), 06 February, 2001 (06.02.01), Examples (Family: none)	2-4
X	JP 2001-107149 A (Kawasaki Steel Corp.), 17 April, 2001 (17.04.01), Examples (Family: none)	2

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 July, 2002 (04.07.02)	16 July, 2002 (16.07.02)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP02/04524

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 10-121205 A (Kawasaki Steel Corp.), 12 May, 1998 (12.05.98), & TW 420719 A	1-4
A	JP 2000-273547 A (Nippon Steel Corp.), 03 October, 2000 (03.10.00), (Family: none)	1-4

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